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Chronic patellofemoral pain syndrome: alternatives for cases of therapy resistance

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Abstract This study compared the efficacy of two approaches to treating therapy-resistant patellofemoral pain syndrome. In a prospective randomized study 20 patients were treated for 8 weeks with 16 physiotherapeutic exercises on a neurophysiological basis (proprioceptive neuromuscular facilitation) while another 20 patients underwent a special training program using a special resistance-controlled knee splint for 15 min three times daily. We measured muscle activity on a Cybex 6000 and performed surface electromyography of the vastus medialis and vastus lateralis muscles. Anterior knee pain was assessed by the Bessette and Hunter score and a visual analogue scale. An increase in electromyographic activity in the vastus medialis muscle and significant improvement in individual comfort were observed only in those treated by knee splint. The knee splint thus proved more effective than proprioceptive neuromuscular facilitation for treating cases of patellofemoral pain syndrome resistant to conservative therapy.

Keywords Patellofemoral pain syndrome · Anterior knee pain · Knee splint

Introduction

Patellofemoral pain syndrome (PFS) has been regarded in recent years as being due to functional and muscular imbalances, following studies reporting no correlation between damage to retropatellar cartilage and manifestation of femoropatellar pain [2, 6, 15, 17, 22]. Discussion of the pathogenesis has focused on increased lateralization due to functional malalignment of the patella, followed by tilting of the latter along with malnutrition and damage of the retropatellar cartilage [5, 13]. These findings on the association between muscular imbalance in concomitance with PFS support the need for therapeutic alternatives to cope particularly with cases resistant to conservative treatment. New, promising therapeutic procedures for treating retropatellar pain have been suggested by studies reporting significant impairment of pain using a special knee splint [16].

This study was undertaken to evaluate the therapeutic benefit of the knee splint with integrated resistance-controlled torque versus physiotherapeutic exercises by proprioceptive neuromuscular facilitation (PNF) in patients with chronic PFS.

Material and methods

Patients

We compared two therapeutic approaches for PFS over a period of 8 weeks in a prospective, randomized, controlled study. Inclusion criteria were: persistence of unilateral retropatellar pain for more than 6 months, unsuccessful conservative therapy, use of anti-inflammatory and analgesic agents, electrotherapy and physiotherapeutic exercises without PNF, and patient age between 16 and 40 years. Excluded were patients with known meniscopathy and damage to their cruciate ligaments, chronic inflammatory processes and femoropatellar arthrosis greater than I° as evaluated according to Fairbank [4]. Prior to the onset of pain symptoms all patients had been active amateur athletes (running, volleyball, basketball) with weekly training of at least 2 h, and each reported a period of limited sports activity due to PFS for at least 8 weeks prior to inclusion into the study.

Patients were randomized to either of the following two therapy groups. Group A included 15 women (mean age 23 years, range 18–28; mean weight 59 kg, range 49–65; mean height 166 cm, range 159–170) and five men (mean age 27 years, range 21–31; mean weight 79 kg, range 69–90; mean height 175 cm, range 169–191). Group B included 13 women (mean age 21 years, range 16–25; mean weight 58 kg, range 50–65; mean height 168 cm, range 162–170) and 7 men (age 26 years, range 18–36; mean weight 75 kg, range 68–91; mean height 178 cm, range 175–188).

Baseline measurements in the two groups were similar on all variables, including distribution of patella types assessed according to Wiberg [19] (type I, 4 in group A and 5 in group B; type II, 11 in group A and 10 in group B; type III, 3 in each group; type IV, 2 in each group).

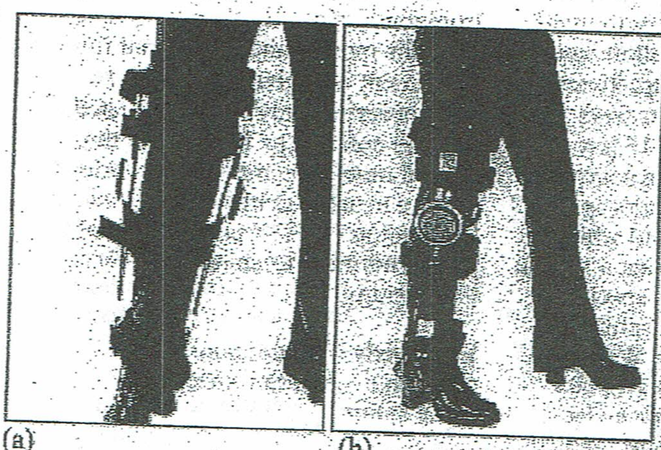


Fig. 1a,b Knee splint. a Frontal view. b Lateral view

Treatment

Patients assigned to group A received 16 rounds of physiotherapeutic exercises based on PNF combined with extension of the tractus iliotibialis and quadriceps femoris muscles. Patients were treated by three therapists on an outpatient basis in two 1-h sessions per week and were not required to undertake additional exercises on their own during the study. Nine treatments were applied to the left knee joint and 11 to the right in group A.

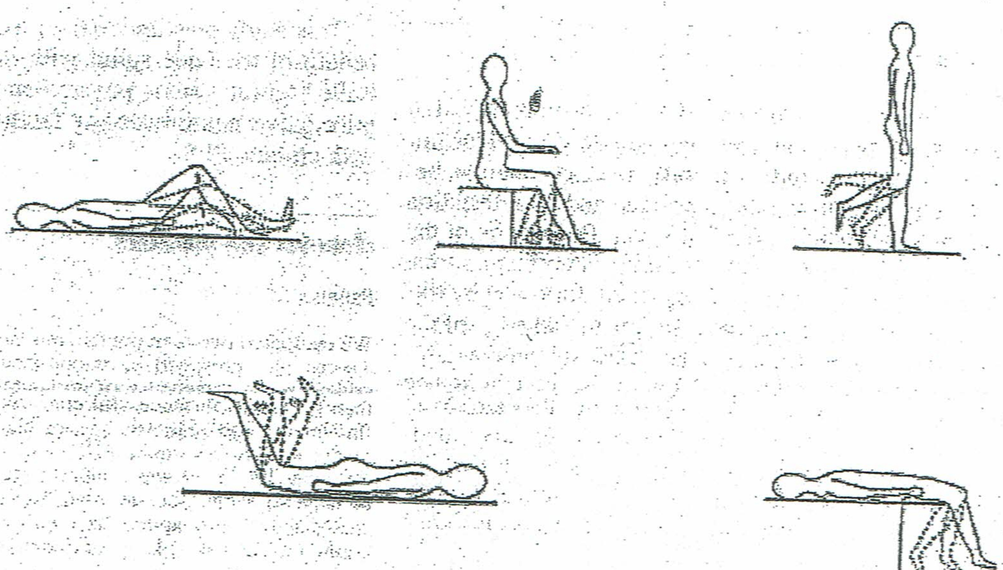
Treatment in group B consisted of unsupported use of a special knee splint (Protonics®, ORMED a Company of EMPI Inc., USA; Fig. 1) for 15 min three times daily combined with exercises performed according to instructions (Fig. 2), along with knee flexion in both knees, to reach an individually preset torque. Exercises were carried out in seated and standing positions to strengthen the ischiocrural musculature. This approach was based on the concept of treatment muscle groups at different isometric activities. The knee splint was fitted with a vertically adjustable bilateral frame and four padded holding straps for fixation to the leg on top of the patient's wear. Hinges with variable torque of 2–17 Nm were bilaterally integrated into the knee frame at the level of the knee-joint gap. For the purpose of the study the torque was individually limited, depending on pain symptoms. Torque levels were preset to enable patients to walk upstairs and downstairs with almost no pain. Seven treatments were applied to the left knee joint and 13 to the right.

Measurements

Results of treatment were compared between the two groups on the basis of three types of examination. These were carried out by an impartial person not involved in the study at baseline and during the 4th and 8th weeks of treatment.

Peak torque of knee extensors and flexors was measured using the Cybex 6000 (Luniar, USA), combined with isokinetic muscle tests under conditions of concentric activity, angular velocity of 60°/s and range of motion of 0–120°. Isometric measurements of electromyographic activity at maximum isometric exposure of vastus medialis (VM) and vastus lateralis (VL) muscles was conducted in 60° knee flexion, using four-channel surface electromyography and a scanning frequency of 1000 Hz (Noraxon, Germany). Adhesive lead electrodes were placed on the VM and VL just above the muscle belly that is palpable under isometric tension. Distances between patellar midpoints and muscle bellies were de-

Fig. 2 Exercise schedule for group B



pain

none	25 points
only with strenuous activity/sports	20 points
only with moderate activity/sports	15 points
with most activity/sports, but not with activities of daily living (ADL)	10 points
with ADLs but does not restrict ADLs	5 points
with ADLs causing restriction of ADLs 0	0 points

swelling

none	10 points
only with strenuous activity/sports	8 points
only with moderate activity/sports	6 points
with most activity, but not with ADLs	4 points
with ADLs but does not restrict ADLs	2 points
with ADLs causing restriction of ADLs	0 points

crepitation

none	5 points
only with strenuous activity/sports	4 points
only with moderate activity/sports	3 points
with most activity, but not with ADLs	2 points
with ADLs but does not restrict ADLs	1 points
with ADLs causing restriction of ADLs	0 points

catching

none	5 points
only with strenuous activity/sports	4 points
only with moderate activity/sports	3 points
with most activity, but not with ADL	2 points
with ADLs but does not restrict ADLs	1 points
with ADLs causing restriction of ADLs	0 points

weakness / giving way

none	5 points
only with strenuous activity/sports	4 points
only with moderate activity/sports	3 points
with most activity, but not with ADL	2 points
with ADLs but does not restrict ADLs	1 points
with ADLs causing restriction of ADLs	0 points

athletics activities

participates at any desired level without restrictions	20 points
all recreational athletics, but not competitive athletic because of knee difficulties	15 points
restricted recreational athletics	10 points
no recreational athletics because of knee difficulties	0 points

ascending stairs

ascends stairs normally nad without pain	5 points
ascends stairs normally nad with some pain	3 points
ascends stiars with good leg lead only	1 points
unable to ascend stairs	0 points

descending stairs

descends stairs normally nad without pain	5 points
descends stairs normally nad with some pain	3 points
descends stairs with good leg lead only	1 points
unable to descend stairs	0 points

running

unrestricted running without pain	5 points
unrestricted running with pain	4 points
restricted running with pain	2 points
unable to run	0 points

walking

unrestricted walking without pain	5 points
unrestricted walking with pain	4 points
restricted walking with pain	2 points
unable to walk	0 points

ADL

unrestricted ADLs without pain	5 points
unrestricted ADLs with pain	4 points
restricted ADLs with pain	2 points
unable to perform any ADLs	0 points

kneeling

painless	5 points
able to kneel with pain	3 points
unable to kneel	0 points

Fig.3 Bessette and Hunter [1] score (maximum, 100 points)

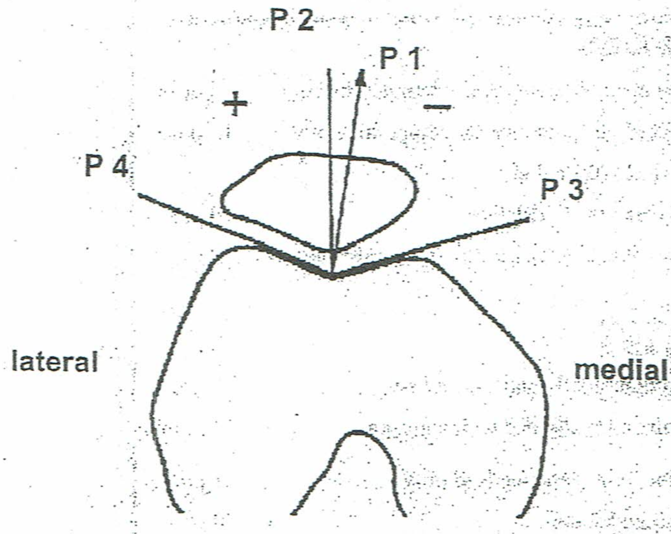


Fig. 4 Patellofemoral congruence angle from tangential conventional radiographic view imaging of the patellofemoral joint [11]

Table 1 Mean value of peak torque (Nm) in the course of treatment

	Group A	Group B
Flexors		
Baseline	64 ± 9	76 ± 8
4th week	78 ± 8	78 ± 8
8th week	82 ± 9	89 ± 7
Extensors		
Baseline	130 ± 7	127 ± 6
4th week	142 ± 8	136 ± 8
8th week	145 ± 7	147 ± 7

termined and compared with each other for better reproducibility of measurements.

Individually perceived comfort was determined at the above time points using a visual analogue scale (VAS) [10] at rest, using the 100-point score of Bessette and Hunter [1] (Fig. 3) prior to muscle tests on the Cybex 6000. VAS in response to loading was evaluated after the isometric and isokinetic muscle tests. Patients were asked to assess their retropatellar pain using a VAS from 0 (no pain) to 10 (greatest imaginable pain).

Joint-specific positive clinical examinations (patellar pain, squatting tests, grinding tests, etc.) were accompanied by radiological diagnosis of the knee joint at two planes and axial patella radiography in 30°, 60°, and 90° knee flexion. This helped to determine the patellofemoral congruence angle (PFC). The PFC is depicted as the angle between P1 and P2 (Fig. 4). For P1 the line is drawn through the lowest point of the patella and the femoral groove, and P2 bisects the angle formed by P3 and P4, which are drawn through the lowest point of femoral groove and highest point of femoral condyle [11].

Peak torques of knee extensors and flexors, mean amplitude of electromyogram of VM and VL, VAS, and score are presented as median, mean, and standard deviation. The unpaired and paired t tests were used to compare results between the two groups. Statistical significance was set at the level of $p=0.05$.

Table 2 Mean electromyographic measurements in vastus medialis (*VM*) and vastus lateralis (*VL*) muscles (μV) and ratios between them

	Group A	Group B
VM		
Baseline	264 ± 10.4	311 ± 9.5
4th week	401 ± 13.8	480 ± 10.4
8th week	456 ± 11.4*	532 ± 8.1**
VL		
Baseline	164 ± 8.9	182 ± 9.9
4th week	225 ± 12.4	284 ± 10.1
8th week	240 ± 13.9*	292 ± 10.2**
VM/VL		
Baseline	1.60 ± 1.3	1.10 ± 1.5
4th week	1.78 ± 1.1	1.69 ± 1.4
8th week	1.9 ± 2.4	1.8* ± 1.3

*$P=0.003$
**$P=0.001$

Table 3 VAS results at rest and after exposure

	Group A	Group B
At rest		
Baseline	4.2 ± 1.3	5.6 ± 1.5
4th week	3.1 ± 1.6	3.5 ± 1.2
8th week	3.9 ± 2.1	3.1 ± 1.2*
After exposure		
Baseline	6.5 ± 1.4	7.0 ± 1.3
4th week	6.0 ± 1.2	3.9 ± 1.2
8th week	6.5 ± 1.5	3.3 ± 1.1*

*$P<0.05$

Table 4 Statistical analysis (*P*) of VAS improvement

	Group A	Group B
Before treatment	0.15	0.00028
After treatment	0.32	0.0010

Results

Radiological examination revealed posttherapeutic reduction in the PFC angle from 10.4±6° to 6.5±3.5° in group A (n.s.) and one from 11.7±6.5° to 2.5±2.0° in group B ($P<0.05$). Isometric and isokinetic Cybex 6000 tests recorded only relatively small increases in peak torques in knee flexors and extensors (Table 1, n.s.) and of VM and VL activities. However, there was a significant increase in VM and VL activity between groups A and B (paired t test), while there was no difference between groups (unpaired t test; Table 2). The Cybex 6000 tests also recorded an increase in maximum torque in knee flexors and extensors and a significant rise in VM activity in both groups.

A significant change in the VM/VL activity ratio to the benefit of VM was additionally recorded in group B.

Patients' individual perception of their condition on the 100-point scale showed an improvement from 53 to 69 points in group A (P=0.003) and one from 53 to 72 points in group B (P=0.0005). Unambiguous alleviation of pain at rest was recorded on VAS in group B (Table 3). There was also a significant difference between the two groups. The unpaired t test for group comparison revealed significant postloading improvement in VAS in group B, VAS with P=0.0065 and score with P=0.0047 (paired t test, Table 4).

Discussion

Statistically significant differences were found between the two therapy groups in this prospective-randomized study following 8 weeks of treatment. The paired t test showed in group B alleviation of pain, as recorded by VAS at rest and after the muscle test exposure. An improvement (unpaired t test) in individual comfort was recorded in each group by evaluation of scores on completion of therapy. Also, comparison between the two therapeutic concepts revealed highly significant reduction in individually perceived pain in the knee-splint group by evaluation of VAS after exposure. Other findings from the Cybex 6000 isometric and isokinetic tests revealed nonsignificant increases in peak torque of knee extensors and flexors and significant increase in electromyographic activity of VM and VL in both groups.

These findings support the knee-joint splint approach as a valuable alternative in cases of therapy-resistant PFS. Intensive submaximum auxometric training combined with use of the knee splint thus provides targeted activation and strengthening of hamstrings, with subsequent straightening and stabilization of the pelvis. Results are likely to include detonization of hip joint flexors, successive reduction in femoral internal rotation, and enhanced control of external/internal tibial rotation [23].

With its progressive resistance to flexion movement, knee splint therapy has an impact on restoration of patellar alignment with optimization of muscular interplay between VM and VL and thus leads to rapid pain relief. Evidence of this is provided by our data on changes in the ratio between VM and VL activities, to the benefit of the VM and radiological confirmation of centering of the patella into the intercondylar groove. This has confirmed study results by Timm [16], who has reported significant reduction in the femoropatellar angle of congruence and centering of the patella towards the femoral trochlea. However, our results from radiological investigation of the PFC provided only the suggestion of a change in group B rather than A. These results support a trend but no change in statistical significance, since the angle of congruence may be affected by the tonus of the quadriceps muscle independently of the therapeutic approach [9, 18]. Further confirmation of the effect on the angle of congruence therefore requires diagnostic use of dynamic magnetic resonance tomography.

The results reported by Timm [16] and other available data support the view that the benefit of the knee-joint splint is based on optimizing pelvis-leg statics, which is impaired in PFS [3, 8, 16]. This view of such impairment in PFS patients is supported by dynamic and static computed tomography findings [3, 20, 22] in which alterations were found to be associated with femoropatellar malalignment and increased external rotation of the tibia.

The hypothesized cause of static disorder involves insufficient stabilization of the pelvis and consequences for the femoropatellar joint. This condition may be due to the ventral and dorsal muscle chains of the trunk and lower extremities. Ventral tilting of the pelvis may be triggered by several phenomena, including insufficient and interacting muscle chains owing to weak abdominal muscles (e.g., obliquus internus muscle, hypertonus of the paraspinal musculature (erector spinae muscle), hyperlordosis of the lumbar spine resulting in shortening of the muscle, and hypertonus of hip-joint flexors (iliopsoas muscle). Concomitant muscular weakness of the gluteus medius muscle and the ischiocrural group may lead to impairment of motion and gait patterns.

Optimization of alignment leads to reduction in lateral pull on the patella, combined with less strain on the median retinaculum and synovium and thus deactivation substance P nerve fibers and other trigger points in this region. This hypothetical explanation, which is supported by bioptic examinations of PFS patients with significantly higher concentrations of substance P nerve fibers than control groups in both the median retinaculum and Hoffa's fat pad [21]. These findings support the theory that soft tissues around the knee are an important factor or trigger point in anterior knee pain syndrome. Patellar lateralization combined with impaired pelvis-leg statics may lead to persistent extension of the median retinaculum and consequently permanent irritation of nociceptors in PFS patients.

Another desirable mechanism of action of the knee splint is improved proprioceptive input to and output from the ischiocrural musculature, with synergistic effects on knee extensor. Increase in electromyographic activity thus induced may bring about improved synergistic neuromuscular interaction of all relevant dynamic and static stabilizers in the knee joint [5, 13, 17, 22].

In summary, the findings of this study show better the individually perceived therapeutic results to be better following knee splint use than those from physiotherapeutic exercises. The knee splint used here is thus confirmed as an effective therapeutic concept for coping with PFS and for achieving early pain relief. The knee splint also enables patients to undertake sustainable self-therapy independently of scheduled therapy deadlines.

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